Coordinated Multi-Agents Based Patient Scheduling Using Genetic Algorithm

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***Abstract* - Scheduling is inevitable and an integral part of hospital management. Effective patient scheduling can improve hospital service quality by minimizing the waiting/stay time for patients in the hospital and operation efficiency by optimizing the utilization of resources. However, in practice, the schedulers usually take substantial amount of time to do the scheduling manually and also by using various traditional scheduling algorithms. Motivated by the real needs in hospital environments this paper focuses on finding an optimal schedule using search based optimization techniques like Genetic Algorithm (GA) and multi-Agents. Agents have been proved to be an effective approach to resource allocation because of its coordination and social abilities. Exact methods such as branch and bound method, and dynamic programming take considerable computing time and hardware requirements in this application domain. Considering the crucial time in the hospital environments, combinatorial search space algorithms (like GA) with precedence constraints have been selected to find a good solution with the following objectives: Customer satisfaction and Operational Efficiency. Customer satisfaction is achieved by minimizing the waiting time for patients and operational efficiency by minimizing the idle time of the resource.**

***Index Terms* - Patient Scheduling, Operational Efficiency, Agents, Customer Satisfaction**

I. INTRODUCTION

The managerial aspect of providing health services to patients in hospitals is becoming increasingly important. Hospitals want to reduce costs and improve their financial assets, on the one hand, while they want to maximize the level of patient satisfaction, on the other hand. Patient Scheduling is the process of scheduling and sequencing the patients for various multiple resources in health care domain. The multiple constraints and multiple goals to be achieved in minimal time makes this problem highly complex. The social abilities allow agents to interact with each other to reach their own goals that help realize adaptiveness and dynamism [1][2][3]. Agents also have the ability to represent specific constraints and preferences as goals and plans which play a major role in many hospital scheduling problems.

As various researches in GA was in progress a powerful automated GA based patient scheduling for highly constrained situations developed by Vili in 1997 guaranteed to produce feasible solution not breaking any of the required constraints [4][5]. In this system schedules were initially selected by random and they were calculated against the fitness function and the fitness is expected to be improved by basic genetic operators like crossover and mutation. This method, together with the whole process of schedule generation showed the important parameters to direct the evolution for using GA for optimizing time constraints in patient scheduling.

II. RELATED WORK

A. *Problem Domain*

Hospital Patient Scheduling is an inherently distributed problem because of the way real hospitals are organized [6]. Moreover the treatment plan is dynamic because it changes with respect to time. Each department maintains a high degree of independence and authority. Each department also has its own policies and preferences regarding the scheduling of their patients and allocation of the resources. Hence this domain is a highly dynamic and an effective solution for patient scheduling will improve the quality of life in the society.

B. *Literature Survey*

Many studies have examined the scheduling problems for providing on time services for hospitals [7]. However, each scheduling problem has its own characteristics [8][9]. In Ref. [10] industrial management, the multi-agent scheduling is formulated as a sequencing game and in project scheduling, its concerned with negotiation which takes place between agents to resolve conflicts when the schedules become unacceptable [11].

III. GENETIC ALGORITHM BASED CMPS SYSTEM

The system design of the Coordinated Multi-agent based Patient Scheduling System (CMPS) using Genetic Algorithm is presented below in Fig. 1. The design and implementation of this system follows the object-oriented approach. The CMPS system contains four main actors: the patient agent, the resource agent, schedule agent and common agent. The common agent is the entry point to this system where the patients are consulted and registered.

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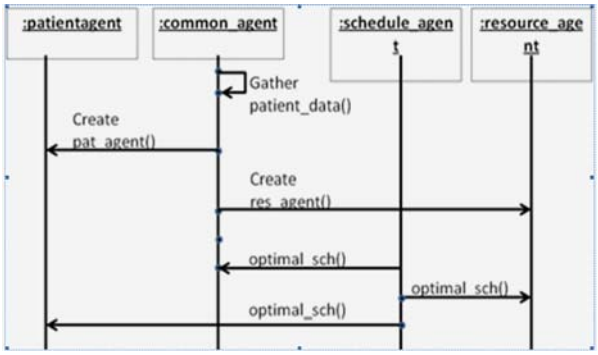

Figure 1. System Design of GA based CMPS

The treatment plan and priority of each patient and resource is generated by this common agent. The optimal schedule is generated by the scheduling agent using genetic algorithm. The proposed system uses genetic algorithm to generate the schedule in minimal time. An outline of the basic steps used by CMPS system is dealt below in few steps.

A. Encoding

This algorithm uses a completion time-based encoding, where each gene is of the form (i, j, c_{ij}) and the length of the chromosome varies as per the number of operations at time, t. A sample encoding scheme for the problem given in the Table 1 is given Fig. 2.

B. Initial Population

The initial population of 50% of total number of combinations with respect to the number of resources and patient agents at a particular time-t in the CMPS system was selected in random and calculated for its fitness value.

C. Fitness Evaluation

The multi-objective patient scheduling with available constraints and functionality related resources is formulated as follows,

1. Let $P_i = \{P_i\}_{1 \le i \le n}$, index i be the set of patients to be scheduled and are independent to each other
2. Each patient P_i has a set of medical therapies called as operational task. Let O_{ikj} be the therapy k that has to be undergone by the patient, P_i in the resource, j
3. Let $R=\{R_j\}_{1 \le j \le m}$, index j be the set of m medical resources
4. Each resource, R_j can process only one operational task at a time
5. Each operational task, O_{ikj} is processed without interruption on the resource R_k for a period of P_{ikj} time units

Two objectives which has been used to evaluate the fitness of the schedule, L is as follows,

1. Minimization of the patient's waiting time
2. Maximization of resource utilization by minimizing the idle time of the resource

$$f(l) = W(l) + I(l) + P(l) \tag{1}$$

where,

W(l) –Total waiting time of Patient
I(l) –Idle time of the medical resource for the schedule, L
P(l) –Penalty value

Table 1 Sample Problem

Patients	No. of Operations	Required Resources	Processing Time
1	3	R1, R2, R3	2, 1, 3
2	2	R2, R3	3, 2
3	3	R2, R3, R4	1, 2, 1

(1, 1, 2)	(1, 2, 3)	(1, 3, 6)	(2, 1, 6)	(2, 2, 8)	(3, 1, 1)	(3, 2, 3)	(3, 3, 4)

Figure 2. Schedule Encoding

The most important parameter used to measure the customer satisfaction is in terms of total waiting time of 'n' patients at time 't' in a schedule (l) is measured by the formula as given below.

$$W(l) = \sum_{i=1}^{n} p_i \left(C_i(l) - A_i(l) - E_i(l)\right) \tag{2}$$

where,

p_i –priority of the patient that indicate the preference of patient i

$C_i(l)$ –completion time of patient i in the schedule l

$A_i(l)$ –arrival time of patient i in the schedule l

$E_i(l)$ –execution time of patient i in the schedule l

Another important parameter used is the resource utilization which is measured in terms of idle time of the resource given by,

$$I(l) = \sum_{j=0}^{m} w_j \left(I_j(l)\right) \tag{3}$$

where,

w_j –weight of the resource

$I_j(l)$ –Idle time of resources j in the schedule l

The penalty function is a summation of two other sub-penalty functions, r(L) and c(L) defined as follows,

$$r(L) = \begin{cases} 0, \text{if } \sum_{k=1}^{m} X_{ijk} = 1 \ \forall i \in P, \forall j \in O_{ij} \text{ at time t} \\ w_m \cdot X_{ijm}, \text{Otherwise} \end{cases} \tag{4}$$

where,

$$X_{ijm} = \begin{cases} 1, \text{if } O_{ij} \text{ is treated on resource m at time t} \\ 0, \text{Otherwise} \end{cases} \tag{5}$$

$$c(L) = \begin{cases} 0, \text{if } \sum_{i=1}^{m} C_{ijr} \le B_{i(j+1)r} \ \forall j \in O_{ij} \\ w_i \cdot (C_{ijr} - B_{i(j+1)r}), \text{Other wise} \end{cases} \tag{6}$$

D. Crossover and Mutation

In this proposed system an order-based crossover and insertion type mutation with respect to the priority are used. The likelihood of applying crossover is typically between 0.6 and 1.0. Normally after crossover, each child is allowed to go through mutation with low rate of 0.1% to 1% probability.

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IV. RESULTS AND DISCUSSION

The basic framework is implemented in Java platform using JADE. The experimental design is outlined below and it was carried out in a HP Pavilion dv6000 laptop with Intel Pentium Dual Core processor T2250 at a speed of 1.73GHz and 1GB RAM.

A. *Performance Evaluation Metric*

The performance of the proposed framework is evaluated using the performance metrics like total completion time, total waiting time and total ideal time. The schedule generated for the 3X3 benchmark problem in Table 2 for the traditional scheduling algorithms such as (First Come First Serve) FCFS, (Earliest Due Date first) EDD, (Longest Processing time first) LPT, (Shortest Processing time first) SPT and WSPT (Weighted Shortest Processing Time first) using MS. LEKIN [12] software is shown in Fig. 4.

There can be several performance metrics used for evaluating this CMPS system. The objective of patient scheduling problem is to minimize patient waiting time and improve the resource utilization in the hospitals.

The following performance metrics are used in evaluating the objective of the system.

1. Completion Time (C_i) **-** This metric for an i^{th} patient P_i refers to the time at which all operations O_{ij} completes its operation in the specified resource.
2. Total Completion Time (□C_i**)** **-** The total completion time metric represents the summation of the completion time (C_i) of all patients.
3. Patient Waiting Time (W_i**)** **-** This metric is the difference between the patient arrival time and completion time of patient i at time t.
4. Total Patient Waiting Time (□W_i**)** **-** The metric is measured by calculating the summation of the Patient duration for all patients at time t.
5. Ideal Time (I_k**)** **-** The resource ideal time metric is the difference between the working time of the resource k and the final completion time.
6. Total Ideal Time (□I_k**)** It is the summation of the ideal time for all the resources at time t.

Table 2: 3X3 Benchmark problem

Patients	Weight w_i	Due date d_i	Resource (processing time) rj(p_{ij})
1	4	10	1(3), 2(1), 3(6)
2	6	10	3(3), 2(7), 2(1)
3	2	12	1(2), 3(4), 2(4)

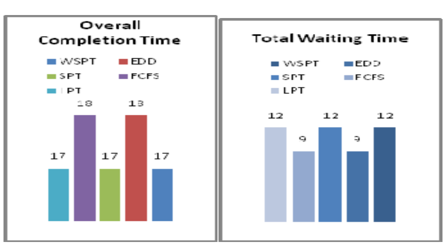

Figure 4. Performance for traditional Scheduling Techniques

V. CONCLUSION

The Coordinated Multi-agent based patient scheduling system using Genetic Algorithm is designed and implemented. This framework is simulated using JADE as a middleware in Java platform for a 3X3 benchmark problem which can be further tested for larger problems. The agent based solution makes this system more flexible and robust. Application of search based optimization techniques like Genetic Algorithm to a highly time-constrained patient scheduling domain will surely benefit the system by minimizing the schedule generation time and hardware requirements. Hence this provides an effective and efficient method to find a qualitative schedule with the basic objective of customer satisfaction and operational efficiency.

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